Activity 3.3.1: What Are Action Molecules?

Introduction: Have you ever heard anyone say, "Build strong bones and muscles, eat protein"? As you read earlier, proteins are a very important type of macromolecule found throughout your body. Proteins not only build the body structures, including muscles and bones, they also are involved in many other functions. Proteins are made from the binding together of amino acids in specific sequences. You could think of the twenty amino acids as letters, and the proteins as long words. Imagine how many words consisting of between 50 and 5000 letters you could make with a twenty letter alphabet! That analogy illustrates the diversity and range in size of proteins. Proteins have a variety of shapes, sizes, chemical compositions, and chemical reactivity. They include thousands of different substances which can be classified into five basic types: structural, regulatory, immunological, transport and catalytic. In this activity, you will focus on the action or catalytic proteins; these proteins, called enzymes, act as catalysts to facilitate chemical reactions.

Chemical reactions are essential for life and occur in all living tissues. Regulating homeostasis depends upon properly maintaining these reactions. Enzymes are an important component for that maintenance. Enzymes are catalysts. A catalyst facilitates or helps a reaction to occur more readily by reducing the energy required for the reaction to occur. The catalyst is not part of the actual reaction, does not change the chemical reaction, and is not permanently altered by reaction. It can be used over and over again to repeatedly facilitate a reaction. Let's use an analogy to illustrate the action of a catalyst.

Suppose you see a new MP3 player. It is the newest version and has many cutting edge features. Your reaction may be that you want to buy the player. Unfortunately, the player costs more money than you have. In this case the amount of energy (money) to drive the reaction (purchase) is too great for the reaction to occur. Now let's suppose that a store has a sale on MP3 players, so the price is reduced to a level you can afford. Now the reaction (purchase) can occur. The catalyst in this analogy was the sale. The sale lowered the amount of energy (money) for the reaction to occur. After your purchase, the sale continued and other reactions (purchases) were made by other people.

Most chemical reactions in the body are dependent upon enzymes. Enzymes are highly specific and work on only one substance called its *substrate*. In this activity, you will learn why enzymes are specific for a particular substrate. You will also investigate if changes in environmental conditions impact how efficiently an enzyme functions. This activity will prepare you for the next project when you will be experimenting with real enzymes.

After completing this activity, you should be able to:

- Explain the lock and key and induced fit models of enzyme function.
- Define the term *substrate*.
- Explain the specificity and significance of the active site of an enzyme.

Part A: Research

1. Use Internet and TTTT/2CNs below to research the following information about enzymes.
    - Definition of enzyme
    - Definition of substrate
    - Importance of enzymes
    - How enzymes are named
    - Where enzymes are made

- Lock and Key model
- Induced Fit model
- Active Sites

2. Take detailed notes with information related to each bullet.
3. Organize and then summarize the information in the form of a detailed outline. Use the outline feature of the Inspiration software. To review how to make an outline, refer to Activity 1.1.5 where you made an outline of the connections between the circulatory and skeletal systems using the Inspiration software.

Part C. Co-enzymes

1. Another aspect of enzyme function involves organic molecules called *co-enzymes*. These molecules are an important part of your diet.
2. Use the Internet to research co-enzymes. Use the bullets below to guide your research. Take notes on each bullet.
    - Describe the function of co-enzymes.
    - Identify three different co-enzymes.
    - Identify foods that are good sources of these co-enzymes.

--TTTT 2CN's ---------------------------

Enzymes Function and structure

Enzymes are very efficient catalysts for biochemical reactions. They speed up reactions by providing an alternative reaction pathway of lower activation energy.

Like all catalysts, enzymes take part in the reaction - that is how they provide an alternative reaction pathway. But they do not undergo permanent changes and so remain unchanged at the end of the reaction. They can only alter the rate of reaction, not the position of the equilibrium.

Most chemical catalysts catalyse a wide range of reactions. They are not usually very selective. In contrast enzymes are usually highly selective, catalysing specific reactions only. This specificity is due to the shapes of the enzyme molecules.

Many enzymes consist of a protein and a non-protein (called the **cofactor**). The proteins in enzymes are usually globular. The intra- and intermolecular bonds that hold proteins in their secondary and tertiary structures are disrupted by changes in temperature and pH. This affects shapes and so the catalytic activity of an enzyme is pH and temperature sensitive.

Cofactors may be:

organic groups that are permanently bound to the enzyme (**prosthetic groups**)

cations - positively charged metal ions (**activators**), which temporarily bind to the active site of the enzyme, giving an intense positive charge to the enzyme's protein

organic molecules, usually vitamins or made from vitamins (**coenzymes**), which are not permanently bound to the enzyme molecule, but combine with the enzyme-substrate complex temporarily.

How enzymes work

For two molecules to react they must collide with one another. They must collide in the right direction (orientation) and with sufficient energy. Sufficient energy means that between them they have enough energy to overcome the energy barrier to reaction. This is called the **activation energy**.

Enzymes have an **active site**. This is part of the molecule that has just the right shape and functional groups to bind to one of the reacting molecules. The reacting molecule that binds to the enzyme is called the **substrate**.

An enzyme-catalysed reaction takes a different 'route'. The enzyme and substrate form a reaction intermediate. Its formation has a lower activation energy than the reaction between reactants without a catalyst.

A simplified picture

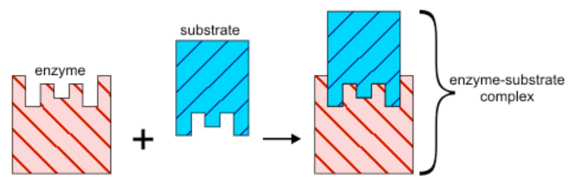
Route A reactant 1 + reactant 2 product

Route B reactant 1 + enzyme intermediate
intermediate + reactant 2 product + enzyme

So the enzyme is used to form a reaction intermediate, but when this reacts with another reactant the enzyme reforms.

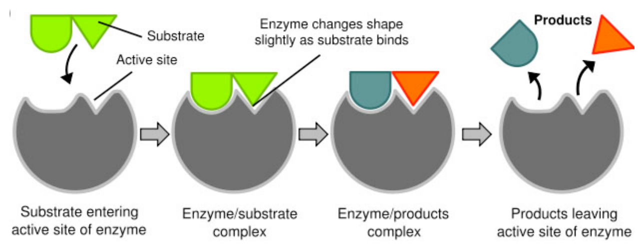
Lock and key hypothesis

This is the simplest model to represent how an enzyme works. The substrate simply fits into the active site to form a reaction intermediate.



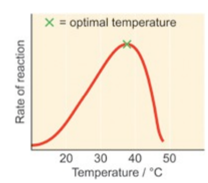
Induced fit hypothesis

In this model the enzyme molecule changes shape as the substrate molecules gets close. The change in shape is 'induced' by the approaching substrate molecule. This more sophisticated model relies on the fact that molecules are flexible because single covalent bonds are free to rotate.

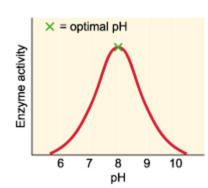


Factors affecting catalytic activity of enzymes

Temperature As the temperature rises, reacting molecules have more and more kinetic energy. This increases the chances of a successful collision and so the rate increases. There is a certain temperature at which an enzyme's catalytic activity is at its greatest (see graph). This optimal temperature is usually around human body temperature (37.5 °C) for the enzymes in human cells.



Above this temperature the enzyme structure begins to break down (**denature**) since at higher temperatures intra- and intermolecular bonds are broken as the enzyme molecules gain even more kinetic energy.

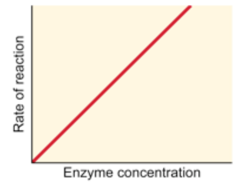


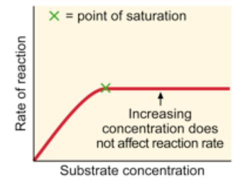
pH Each enzyme works within quite a small pH range. There is a pH at which its activity is greatest (the optimal pH). This is because changes in pH can make and break intra- and intermolecular bonds, changing the shape of the enzyme and, therefore, its effectiveness.

Concentration of enzyme and substrate

The rate of an enzyme-catalysed reaction depends on the concentrations of enzyme and substrate. As the concentration of either is increased the rate of reaction increases (see graphs).

For a given enzyme concentration, the rate of reaction increases with increasing substrate concentration up to a point, above which any further increase in substrate concentration produces no significant change in reaction rate. This is because the active sites of the enzyme molecules at any given moment are virtually saturated with substrate. The enzyme/substrate complex has to dissociate before the active sites are free to accommodate more substrate. (See graph)





Provided that the substrate concentration is high and that temperature and pH are kept constant, the rate of reaction is proportional to the enzyme concentration. (See graph)

Inhibition of enzyme activity Some substances reduce or even stop the catalytic activity of enzymes in biochemical reactions. They block or distort the active site. These chemicals are called **inhibitors**, because they inhibit reaction.

Inhibitors that occupy the active site and prevent a substrate molecule from binding to the enzyme are said to be **active site-directed** (or **competitive**, as they 'compete' with the substrate for the active site).

Inhibitors that attach to other parts of the enzyme molecule, perhaps distorting its shape, are said to be **non-active site-directed** (or **non competitive**).

Immobilized enzymes Enzymes are widely used commercially, for example in the detergent, food and brewing industries. Protease enzymes are used in 'biological' washing powders to speed up the breakdown of proteins in stains like blood and egg. Pectinase is used to produce and clarify fruit juices. Problems using enzymes commercially include:

they are water soluble which makes them hard to recover
some products can inhibit the enzyme activity (feedback inhibition)

Enzymes can be immobilized by fixing them to a solid surface. This has a number of commercial advantages:

the enzyme is easily removed
the enzyme can be packed into columns and used over a long period
speedy separation of products reduces feedback inhibition
thermal stability is increased allowing higher temperatures to be used
higher operating temperatures increase rate of reaction

There are four principal methods of immobilization currently in use:

covalent bonding to a solid support
adsorption onto an insoluble substance
entrapment within a gel
encapsulation behind a selectively permeable membrane